

10:51:46

OCA PAD AMENDMENT - PROJECT HEADER INFORMATION

07/05/91

Active

Project #: B-04-618
Center # : R5574-1A9

Cost share #: VARIOUS
Center shr #:

Rev #: 38
OCA file #:
Work type : RES
Document : GRANT
Contract entity: GTRC

Contract#: ECD-8300965
Prime #:

Mod' #: ADMIN REV

Subprojects ? : Y
Main project #:

CFDA: 47.041
PE #: N/A

Project unit: MHRC Unit code: 03.010.204
Project director(s):
PENCE I W MHRC (404)894-2362

Sponsor/division names: NATL SCIENCE FOUNDATION / GENERAL
Sponsor/division codes: 107 / 000

Award period: 830101 to 920229 (performance) 920531 (reports)

Sponsor amount	New this change	Total to date
Contract value	0.00	1,187,000.00
Funded	0.00	1,187,000.00
Cost sharing amount		1,416,451.00

Does subcontracting plan apply?: N

Title: MATERIAL HANDLING RESEARCH CENTER

PROJECT ADMINISTRATION DATA

OCA contact: Mildred S. Heyser 894-4820

Sponsor technical contact Sponsor issuing office

ALEX SCHWARZKOPF
(202)357-7307

DIONIE HENRY
(202)357-9626

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ENG/CDR
WASHINGTON, DC 20550

NATIONAL SCIENCE FOUNDATION
DGC/ENG
WASHINGTON, DC 20550

Security class (U,C,S,TS) : U
Defense priority rating : N/A
Equipment title vests with: Sponsor

ONR resident rep. is ACO (Y/N): N
NSF supplemental sheet
GIT X

Administrative comments -

PERFORMANCE AND REPORTING DATES EXTENDED VIA OPAS - *No del. schedule*

Final Report already submitted.



GEORGIA INSTITUTE OF TECHNOLOGY
OFFICE OF CONTRACT ADMINISTRATION

NOTICE OF PROJECT CLOSEOUT

Closeout Notice Date 05/12/92

Project No. B-04-618 _____ Center No. R5574-1A9 _____

Project Director PENCE I W _____ School/Lab MHRC _____

Sponsor NATL SCIENCE FOUNDATION/GENERAL _____

Contract/Grant No. ECD-8300965 _____ Contract Entity GTRC

Prime Contract No. _____

Title MATERIAL HANDLING RESEARCH CENTER _____

Effective Completion Date 920229 (Performance) 920531 (Reports)

Closeout Actions Required:	Y/N	Date Submitted
Final Invoice or Copy of Final Invoice	N	_____
Final Report of Inventions and/or Subcontracts	N	_____
Government Property Inventory & Related Certificate	N	_____
Classified Material Certificate	N	_____
Release and Assignment	N	_____
Other _____	N	_____

Comments BILLING VIA LINE-OF-CREDIT. _____

Subproject Under Main Project No. _____

Continues Project No. _____

Distribution Required:

Project Director	Y
Administrative Network Representative	Y
GTRI Accounting/Grants and Contracts	Y
Procurement/Supply Services	Y
Research Property Management	Y
Research Security Services	N
Reports Coordinator (DCA)	Y
GTRC	Y
Project File	Y
Other _____	N
_____	N

NOTICE OF PROJECT CLOSEOUT (SUBPROJECTS)

Sponsor NATL SCIENCE FOUNDATION/GENERAL

Project #	B-04-F12	PD BOHLANDER R A	Unit	03.010.204	T
GRANT #	ECD-8300965	MOD#	OPENED IN ERROR	MHRC	*
Ctr #	10/24/6/R5574-1A7	Main proj #	B-04-618	OCA CO	MSH
Sponsor-NATL SCIENCE FOUNDAT	/GENERAL				107/000
MATERIAL HANDLING RE					
Start	830101	End	920229	Funded	15,000.00
				Contract	15,000.00

GEORGIA INSTITUTE OF TECHNOLOGY
OFFICE OF CONTRACT ADMINISTRATION

NOTICE OF PROJECT CLOSEOUT (SUBPROJECTS)

Project # B-04-601 PD PENCE I W Unit 03.010.204 T
GRANT # ECD-8300965 MOD# MHRC *
Ctr # 10/24-6-R5574-1A8 Main proj # B-04-618 OCA CO MSH
Sponsor-NATL SCIENCE FOUNDAT /GENERAL 107/000
MATERIAL HANDLING RE
Start 890824 End 910831 Funded 14,170.26 Contract 14,170.26

Project # B-04-648 PD PENCE I W Unit 03.010.204 T
GRANT # ECD-8300965 MOD# ADMIN MHRC *
Ctr # R5574-1A6 Main proj # B-04-618 OCA CO MSH
Sponsor-NATL SCIENCE FOUNDAT /GENERAL 107/000
MATERIAL HANDLING RE
Start 830101 End 910831 Funded 10,541.08 Contract 10,541.08

Project # E-24-685 PD PLATZMAN L K Unit 02.010.124 T
GRANT # ECD-8300965 MOD# ISYE *
Ctr # R5574-1A3 Main proj # B-04-618 OCA CO MSH
Sponsor-NATL SCIENCE FOUNDAT /GENERAL 107/000
MATERIAL HANDLING RE
Start 830101 End 910831 Funded 14,064.00 Contract 14,064.00

Project # M-23-654 PD KAATZ J R Unit 02.010.182 T
GRANT # ECD-8300965 MOD# BUD REV 6/22/90ECONOMICS *
Ctr # R5574-1A2 Main proj # B-04-618 OCA CO MSH
Sponsor-NATL SCIENCE FOUNDAT /GENERAL 107/000
MATERIAL HANDLING RE
Start 830101 End 910131 Funded 24,000.00 Contract 24,000.00

LEGEND

1. * indicates the project is a subproject.
 2. I indicates the project is active and being updated.
 3. A indicates the project is currently active.
 4. T indicates the project has been terminated.
 5. R indicates a terminated project that is being modified.
-

II. Research Programs

A. Factory Automation

1) Completed Work

The charge to the Factory Automation Program is to define and investigate material handling issues related to automation in the factory. During the first year there were eight active projects which can be classified into several categories. The project on simulation addressed fundamental methodology for evaluating material handling systems. The results of this project reduces the cost and turnaround time for simulation analyses and should impact both design and planning and control activities.

The project on kitting focuses on a widely accepted but, apparently, little understood practice. The goals of the project were to develop a better understanding of the direct impacts of kitting as well as the hidden agenda associated with kitting. After several attempts to characterize the kitting process with a microcomputer program analysis the research program was given new direction.

There are several research tasks addressing "first generation" automation problems by developing cost and performance models. Handling systems that support a version of flexible manufacturing have been considered; small lot storage systems were analyzed, and some new AS/RS concepts were investigated. Results of these tasks will impact not only system design, but equipment operation as well. The project on systematic lot size planning addressed a fundamental problem in "second generation" automation, viz., in batch manufacturing, what should be the size of each unit load? The answer to this question has a major impact on storage and handling equipment utilization. There are two projects that address the planning and control issues associated with "third generation" automation. The scheduling task is concentrating on developing advanced scheduling/sequencing methodologies that are useful in the real shop environment. The task on planning for flexible manufacturing is developing a methodology for assigning operations and jobs to flexible work stations. Results of these projects are essential ingredients for successful third generation projects.

2) New Work

The work in automated storage and retrieval systems will be continued and will address additional issues such as acceleration, and optimum crane dispatch algorithms.

In centralized WIP handling systems the next project will include completion of work already started and additionally will address the problem of jointly specifying the centralized WIP storage subsystem and the WIP handling subsystem.

The goal of kitting is to build a foundation for developing the necessary tool for analyzing kitting as a function. The approach will be to build a generic data-driven description of kitting which will be used for specific kitting operations.

Research during the first year in automated scheduling started from specific problems and developed specific models and results. In the current year generic automated factory scheduling model will be developed and used as a framework for organizing the research.

Currently research in work-in-process management is focused on a single-card Kanban environment, which is a combination of push, or schedule-based and pull, or usage-based control. This project is a continuation from the last year.

Specific project activities for FMS loading and routing will be:

1. Develop a large realistic description of a typical problem;
2. Evaluate the database for exploitable special structure;
3. Develop prototype computer implementation for one or more algorithms;
4. Evaluate and refine algorithms using the demonstration database.

B. Robotics and Material Handling

1) Completed Work

Research in four areas important to more effective implementation of robotic devices in material handling were undertaken: 1) technology of lightweight arms, 2) requirements for software structures for control of automation, 3) low-cost sensors (initially tactile tables) and 4) microprocessor based control of two coordinated arms.

The lightweight arm research is built around technology to control flexible structures. By relaxing the constraint that links in an arm are rigid, a large reduction in arm weight appears possible. Research areas include the necessary control algorithms and the application of advanced technologies in drives, structures, and power transmissions. The initial investigations concerned dynamic modelling and control, D.C. moving coil motors, passive damping techniques, and efficient structural configurations including application of high strength/ stiffness composites.

Results thus far include a report to member companies on the state-of-the-art of D.C. moving coil motors including an analysis of how motor requirements are related to simplified robot tasks. An initial study of passive damping as applied to robotic arms has been completed and preliminary results are favorable. In robots and other motion control systems it appears to offer a means of helping reduce oscillations and improving stability in manipulators.

The objective of the tactile research is to implement an array of displacement/force sensors in the form of a horizontal table. The table would be used identify and locate objects by the contour and weight distribution as measured by the table. Progress has been made on development and acquisition of software for processing tactile data from the sensor system and a report has been distributed on the characteristics of known tactile data processing software. An 8-bit parallel interface has been constructed to tie the tactile sensor through a RS232 interface

to other computers. Other computers available for research are an HP1000, Autovision IV vision system, VAX 750 and an IBM PC. Software for processing the tactile data from the tactile sensors has been programmed for an IBM PC. An effort to adapt the Automatix IV vision system to the tactile sensor is in process.

The coordinated arm research consisted of basically two problems which were the subject of this research. The problems were: 1) the interaction of the two robots can lead to instability or oscillatory response and 2) the interaction requires that the arms move in a coordinated manner. This research addresses these problems by implementing coordinated control of two PUMA robots-- one a six axis machine, the other a five axis machine. The efforts thus far have resulted in all the hardware for the coordinated control of two PUMA robots being completed. This system is an all new three level system controller using 16 Intel 8086 microprocessors. All of the software associated with the 11 axis controllers, the 4 motion predictor computers and the 8089 based I/O computer have been implemented. A technical report is in preparation which covers the methodology and results of the coordinated control of two robot arms.

The purpose of the research in software structures was to develop a rational set of requirements for a language or languages that would best suit the needs of automated manufacturing and material handling. Five robot programming languages have been studied: AML, VAL, MCL, RAIL, and AL. That study revealed three issues further examination.

- a. Additional flexibility was needed in the languages to relieve the effort required for reprogramming when there were changes in material handling environments.
- b. Additional flexibility was needed for dynamic environments.
- c. Special purpose robot programming languages were not adequate for material handling applications in general.

Investigation of the first issue was initiated by examining the use of ADA, a general purpose programming language with data abstraction capability, as a tool for robotic programming. Investigation of the second issue began via conceptual design of a knowledge-based system for a mobile cart that adapted to a dynamic environment.

2. New Work

In the light weight arms area four principal activities are planned: 1) construction and test of a single degree of freedom flexible arm for the purpose of determining the potential performance characteristics of motion systems using the proposed light weight technologies, 2) development of a comprehensive set of alternative approaches to control fo flexible arms including time-optimal, quadratic optimal, pole-zero placement and trajectory planning for "good" performance, 3) research on alternative drive train technologies including particularly cable and band type systems and 4) detailed evaluation of brushless motors. The latter two areas are new. The first

item, the experimental arm, will provide for test and evaluation of all analytical results as well as provide a test bed for some of the work in advanced sensors.

The principal task in the tactile sensing area is to complete a system in which the Lord Corporation tactile sensors are used to identify and locate objects and interface this in a manner to allow a robot to manipulate the objects. This is likely to be accomplished by adapting the Automatrix system for tactile data processing.

An initial look at novel sensing technologies will be begun because of the cost and operational problems of current commercial tactile sensors.

C. Advanced Sensors for Material Handling

1. Completed Work

In the advanced sensors area the project team has reviewed and compared alternatives within three sensor technology areas that may be used for location and control of industrial manipulators. The three technology areas are fiber optic sensors, visible and IR tracking and homing, and millimeter wave systems. A particular benchmark application considered is the control of the end effector of a flexible robot arm. Increased attention has also been given to AGVS applications.

Work this year in the area of fiber optics sensors established that there is sufficient sensitivity in the present state of the art to measure strains in robot arms as well as perform inertial guidance involving both acceleration and rotation sensing. Performance of fiber optics sensors was assessed regarding requirements for large dynamic ranges, compactness, and robustness. According to recent literature many different approaches have been tried to obtain high dynamic range but no definitive review has been published of this topic.

In this area of visual and infrared tracking systems, it has been shown to be feasible to track a robot manipulator in a cube four meters on a side with a staring tracking system. This is a simplified tracker that incorporates a wide field of view camera pointed in a fixed direction rather than one with a narrow field of view and servo-controlled pointing. A model has been developed which clarifies the sensitivity-resolution tradeoffs for such a camera in tracking or related applications. When the tracking accuracy is a little better than a millimeter in terms of the derived position of the manipulator and when the tracking volume is that given above, then position sensitive photodiode camera is being used at the limit of its capability. Much less demanding applications are ones involving shorter ranges between the camera and the beacon it is following. Two such systems have been studied; namely, a system which measures flexible arm sag, and one which rides on the manipulator and gives it a capability to home on a target. It has been shown that position sensitive photodiode cameras give excellent range sensitivity for beacon targets in an array of known size. Such arrays would be set up near pick or place locations in a material handling system. Methods have also been found which give adequate angular orientation sensitivity in homing applications. Also, conceptual designs were developed for low cost lens systems appropriate for use

in homing.

In the area of millimeter wave systems, basic guidelines for use in potential industrial ranging applications have been worked out, and discussions with member companies have covered other possible applications such as non-invasive testing. A preliminary bibliography of fiber optic acceleration, rotation, and strain sensors has been completed and is in the process of being issued with a full technical report.

2. New Work

The major milestones for the infrared tracking and homing project are the assembly of the preliminary sensors and amplifiers and the first work with the preliminary robot arm. The next step will be a detailed analysis determining resolution, stray reflection, etc. Finally, more complete tests of tracking and homing will be performed with the robot arm and, if possible, work on advanced modulation/demonstration schemes.

The long term goal of the breadboard fiber optics sensors is a demonstration for the application of such sensors to robot arm control or to guidance of an AGV. The proposed research is the development of schemes which filter out accelerations and rotation rates that are not allowed by the control system and thereby relax the present requirement for ultra-low drift sensors. Another area is the description of signal processing procedures which separately handle high acceleration and low acceleration regimes and the handoff between these cases.

D. Packing/Containerization

1. Completed Work

This project resulted from member company requests and has required substantial focusing through interactions with companies and investigations into the literature. One of the basic problems results from the wide spectrum of problems that exist in this area both inside the facility as well as in the distribution aspect of the business. A review of the literature revealed substantial work in the packaging area but very little work in the literature about containers designed for automated manufacturing. At this point it was decided that it was appropriate to do some on-site visits to observe problems that exist and determine container characteristics- physical and use. To establish tabular data a questionnaire was established which allowed the collection of the same data from each facility. The data have been tabulated and graphed and presented to the member companies.

2. New Work

The work during the second year is to focus on the development of a model and methodology to determine characteristics and quantity of containers to be used in automated manufacturing given a particular set of parameters. It will be developed as a simple model, beginning with determining physical size and shape of the container from part size distribution.

E. Warehouse Automation

1. Completed Work

The research tasks in the warehouse automation area include the development of general procedures for the analysis and design of equipment systems that appear to be different but are conceptually similar, and specific procedures that are applicable to only one type of equipment system.

a) Design Procedure for Fixed-Path Closed-Loop Material Handling Systems

A large number of material handling systems can be described as fixed-path, closed-loop systems. Included in this category are AGVS, towline, monorail, cartrac, other types of conveyors, etc. The objective of this task is to develop a procedure that will enable a designer to specify the best loop configuration and operating characteristics for given input/output rates at known points. Results thus far include a fixed-charge (0-1) network flow algorithm as well as defining a network formulation which considers path construction cost, spur construction cost, maximum delay of main-line vehicles at a spur, and the cost of vehicles. Cost and performance data for typical AGVS have been obtained.

b) Assignment and Scheduling Algorithms for Storage/Retrieval Systems

The purpose of this task was to develop and test fast, effective heuristic algorithms for operating automated storage devices. It is applicable to mini-load, carousel, man-aboard, pallet racks, etc. A number of mathematical properties have been obtained concerning the newly developed picking algorithms. These picking algorithms are based on assigning storage locations for items so that they may be picked in clusters.

c) Minimal Technology Routing Systems

The objective of this task was to discover and test fast, effective, heuristic algorithms for sequencing spatially distributed operations. It is exploring applications to warehouse picking strategies, and efficient location of items within the warehouse. Results include a procedure for the three-dimensional case.

d) An Analysis of Economic Trade-offs in Order Sortation and Accumulation Systems

This study was concerned with the analysis of cost and performance characteristics of state-of-the-art sortation/accumulation systems. The object was to identify critical design parameters that have a direct impact on the type of system to be used and to study the relationship between a given set of parameters and the performance of a particular configuration. Economic trade-offs are presented for alternative configurations with similar performance capabilities. For distribution systems, the study of cost and performance trade-offs for a specific configuration involving recirculation vs blocking was extended to in-

clude number of lanes, induction capacity, extent of clustering, and decision-making-on-the-fly. A technical report has been prepared which details this.

e) Analysis of Performance Characteristics of Small Parts Storage Alternatives

The objective of this task is to develop cost, space, and throughput measures for these types of systems under various assumptions and replenishment - withdrawal rates and storage assignments. This task involves the application of techniques being developed under other tasks. This year the program for assigning items to storage drawers has been tested further, and some modifications have been made. Procedures have been developed for applying the program to operating environments other than dedicated by size. For flow racks there has been developed an overall approach that includes rack cost, floor cost, conveyor cost, and picking and replenishment labor cost. The technical report on storage drawers is almost complete.

2. New Work

The research proposed for the second year consists of continuation of research on five projects and the initiation of two new tasks.

a) Design Procedure for Fixed Path Closed/Loop Material Handling Systems

It is planned that a complete design procedure for fixed path, closed loop material handling systems, consisting of the network algorithm plus the simulator developed at VPI, will be demonstrated on an example problem. The procedure and results will be documented in a MHRC report.

b) Assignment and Scheduling Algorithm for Storage/Retrieval Systems

It is planned to finish the report on retrieval strategies for carousel conveyor and prepare a companion report on storage strategies.

c) Minimal Technology Routing Systems

An MHRC report on the minimal technology routing procedure will be prepared.

d) Analysis of Economic Trade-offs in Order Sortation and Accumulation

Future work on economic trade-offs in order sortation and accumulation will examine more sophisticated control systems, such as the freedom to assign the lanes, as well as examine applications to robots placing items in flow racks.

e) Analysis of Performance Characteristics of Small Parts Storage Alternatives

During the second year, it planned to demonstrate the models for shelving, flow racks, and carousels on a basis consistent with that for storage drawers; reports will be prepared on these systems.

f) Stock Location and Dispatching in Distribution Systems

An algorithm is to be developed and tested for solving the stock location and dispatching problem with timing constraints. A technical report detailing the procedure will be prepared.

g) Algorithms for In-the-Aisle Order Picking

The optimum division of a rectangular area into picking and reserve areas for single and dual command systems is to be investigated for multi-stop picking where vertical travel is not important. The effect of pallet life for picking will be examined. An analysis of separate picking and reserve areas will be performed. Different unit storage costs and different unit load sizes will be considered for the two areas.

F. Logistics

1. Completed Work

The objective of the three logistics projects was to utilize the computer to assist distribution system personnel in making appropriate decisions concerning routing of their vehicles.

a) Management Information Systems for Local Delivery

The objective of this research was to develop a test of methodology which identifies map coordinates for customers from an MIS data base. It is being utilized to determine a set of least cost routes for the delivery problem. The approach utilized in this research is to evaluate the applicability of the nine-digit zip code system to locate customers on a map. The customers for two representative days have been located on the maps. We were unsuccessful in obtaining maps used to layout the ZIP+4 for the counties, but a digitized system for the 5 digit zip code system was located and these digitized centroids will be used to digitize each customer location on the routes.

b) Interactive Routing Code Development

Interactive Route Generator (IRG) is a prototype computer model designed to handle routing and delivery problems. The system, as currently implemented, consists of Basic software on a colorgraphics Chromatics CG 1999 connected in real time to a host mainframe computer.

The initial implementation totally saturated the resources of the Chromatics 1999 and there is no room for enhancements without migrating to a computer with the capacity to add more memory. The current project effort was the migration of the software to a Chromatics 7900.

The Chromatics 7900, with its much greater memory capacity, reliable Winchester technology, and more powerful 68000 processor, allows the consolidation of the host software and the Chromatics 1999 software into one computer. The migration brought the following benefits:

- Permits the enhancement of the software to solve more complex problems;
- Provides more extensive and higher resolution graphics capability;
- Reduces operating cost and telephone line dependence by permitting stand alone operation of the system.

The current plan for the migration is for phased implementation. The first phase moves the host software to the Chromatics 7900. This was the easiest phase and was accomplished in conjunction with the process of learning about the 3 machines.

The second phase is the replacement of the mainframe host computer with the 7900 as the host computer. This allows a thorough checkout of the migrated software and will allow the use of the new machine as soon as possible.

The third phase was the implementation in FORTRAN '77 of a screen on the 7900 to duplicate the display on the 1999. This will allow an assessment of the graphics capabilities using FORTRAN '77 and determine its suitability as the language for the interaction portion of the application.

The fourth phase is to implement the interactive portion of IRG in the chosen language on the 7900, taking care to build in as much portability and changeability as can be accomplished in a reasonable amount of time.

c) Line Hauls with Back Hauls

The project consists of improving scheduling of vehicle deliveries and pickups for line haul operations. In this problem, a set of deliveries are made along a line from a central distribution center to a set of selected points of increasing distance from the center. On its return route, the vehicle will make pickups to be sent to the distribution center. The goal is the development of an interactive algorithm for scheduling these deliveries/pickups in an optimal manner which will provide the ability for frequent review and alteration to existing routes.

The existing routes for the database are being loaded into the Interactive Routing Generator (IRG) computer package. All work up to development of an optimizing algorithm has been completed.

2) New Work

Two projects will be continued from 1982-83; one new project will be initiated in 1983-84.

The demonstration database collection phase for the management information system in routing project is complete. The effort for the

coming year will focus on the development and implementation of models and methodology for employing customer location information in interactive routing systems. The demonstration database will be used to test the algorithms developed.

The line-hauls with back-hauls project will concentrate on the development and testing of models for decomposing the line-hauls and back-hauls problems. Interfacing methodology will be developed to accomplish the necessary linkage between these two problems. The demonstration database collected during 1982-83 will be employed to test the resulting algorithms.

New research will begin on a project involving dynamic dispatching in a routing and scheduling logistics environment. The goal of this effort is the development of interactive graphics models and algorithms for aiding dispatches, in a real time environment, to make critical decisions relative to developing, initiating and revising vehicle routes.

F. Material Control: Quality

1. Completed Work

The goal of this research was to identify the aspects of material handling systems that affect the system's ability to deliver the handled material to the right position at the right time in the right condition. Once these factors are identified, system performance capabilities can be modeled as a function of failure modes and reliability of major system components. The resulting model combines failure mode probabilities with the effect of the modes to determine a component's contribution to the degradation in performance effectiveness of the system. The model will then combine the effects of individual components to arrive at overall system performance effectiveness.

a) Performance Capability Modeling of Small Parts Storage and Retrieval Systems

Research efforts concentrated on defining multivariate performance measures that would adequately describe performance effectiveness and on identifying subsystems and components which contribute to overall performance effectiveness. Latter research has concentrated on the development of a specific model to estimate performance effectiveness based on component failure modes and effects. The model development was completed as a masters thesis and distributed to member companies.

2. New Work

This project will not be continued during this year.

B-04-618

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Refer to: FGC/B-10-618
02.107.000.84.098

20 January 1984

Intergovernmental Science
and Public Technology
National Science Foundation
1800 G Street, N.W.
Washington, DC 20550

Attention: Alex Schwarzhopf, Program Official

Subject: Grant No. IS1-8300965; Request for 2nd Year Funding
for Continuing Grant entitled, "Industry/University
Cooperative Research Center for Material Handling"

Gentlemen:

In accordance with NSF Grant Policies, the GTRI is pleased to submit the Request for Continued Support on the subject research project.

We believe that the enclosed material will provide you with all necessary information. However, if additional information is required, please contact Dr. John White at (404) 894-2362 concerning the technical program. Contractual matters should be referred to the undersigned at (404) 894-4815.

We appreciate the opportunity of submitting this request and look forward to the possibility of continuing our work with you on this project.

Cordially.

Faith G. Costello
Contracting Officer

FGC/ck

Addressee: In Duplicate
Enclosures: Request for Continued Support - In triplicate



MATERIAL HANDLING RESEARCH CENTER
A. FRENCH BUILDING
404-894-2362

January 12, 1984

Mr. Alex Schwarzkopf
Intergovernmental Science
and Public Technology
National Science Foundation
1800 G Street NW
Washington, DC 20550

Dear Mr. Schwarzkopf:

The purpose of this letter is to request second year funding from the National Science Foundation for the Material Handling Research Center located at Georgia Institute of Technology. As indicated in our initial proposal, second year funding of \$200,000 is requested from the National Science Foundation.

The start-up of the Center was extremely successful, with 23 founding member companies actively participating in the MHRC. The proposed budget for the second year of operation is given in Exhibit I. A listing of the member companies is given as Exhibit II. Exhibit III provides a review of the establishment of the Center, as well as descriptions both of research performed during the first year and of research proposed for the second year.

To date, 12 technical reports have been published. We expect to publish approximately 20 technical reports during the second year of operation for the Center.

The Industry Advisory Board has authorized the addition of two additional member companies for the Center. Membership interest has been expressed by more than 30 firms. Hence, we do not anticipate any difficulties in filling the membership positions.

Among the major accomplishments during the first year was the receipt of over \$750,000 in equipment grants. Litton UHS donated \$600,000 of state-of-the-art material handling equipment; IBM donated \$100,000 of their equipment, including two 7535 robots and PC computers; SI Handling Systems donated \$60,000 of mini-cartrac equipment to interface with automation equipment already available. Additionally, several other member companies have pledged to install their equipment for use by the MHRC. We anticipate equipment grants during the second year will total approximately \$100,000.

Approximately 18 research faculty, 25 graduate research assistants, and 5 support personnel were actively involved in the activities of the MHRC during the first year's operation. Turnover of research faculty and graduate research assistants has occurred. However, fortunately, there has been no turnover on the management team for the Center.

Mr. Alex Schwarzkopf

Page 2.

January 12, 1984

As Center Director, I report to the Vice President of Research. Reporting to me are 6 Program Managers: Mr. R. Dale Atkins, Dr. Ron Bohlander, Dr. Steve Dickerson, Dr. John Jarvis, Dr. Leon McGinnis, and Dr. Gunter Sharp. Mr. Atkins also serves as Associate Director of the Center. Additionally, during the second year a full-time Administrative Assistant, a full-time bookkeeper, and two full-time secretaries will support the activities of the Center. One and one half of the support positions are funded from the returned overhead from the first year's operation of the Center; as such, they do not show in the budget figures.

National Science Foundation support will be used primarily to support the administration of the Center. One lesson learned during the first year was the need for strong administrative support. The reporting, travel, and meeting requirements associated with industry/university cooperative research are not insignificant. As noted above, additional secretarial and bookkeeping support are planned for the second year.

The annual membership fee for industrial members continues to be \$30,000. Georgia Tech continues to commit annual support for the Center totaling at least \$200,000. Georgia Tech also returns to the Material Handling Research Center at least 50 percent of the overhead generated by the Center. Additionally, Georgia Tech's President and Vice President for Research have been extremely supportive of the Center; they have indicated that personnel and equipment support will be provided to meet the needs of the MHRC.

The feedback received from the member companies indicates a high degree of satisfaction with the performance of the Material Handling Research Center. We are confident that the Center will continue to grow and receive international recognition for its contribution to its members and the field of material handling.

We appreciate very much the support received from the National Science Foundation and look forward to continued support during the second year. If you have any questions regarding the Material Handling Research Center, please do not hesitate to convey them to me.

Very truly yours,

John A. White, Ph.D.
Director

JAW:lm

cc: Dr. T. E. Stelson
Dr. A. B. Sheppard
Dr. F. A. Rossini
Dr. M. E. Thomas
Mr. G. D. Hutchinson

To: Lynn Boyd
5-21-85

GEORGIA TECH RESEARCH CORPORATION

ADMINISTRATION BUILDING
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ATLANTA, GEORGIA 30332 -0420

Telex: 542507 GTRIOCAATL
Fax: (404) 894-3120

Phone: (404) 894- 4814

28 January 1985

Refer to: LB/B-10-618
03.107.000.85.002

Intergovernmental Science and Public Technology
National Science Foundation
1800 G Street, N.W.
Washington, DC 20550

Attention: Alex Schwarzkopf, Program Official

Subject: Grant No. ISI-8300965; Request for Third (3) Year Funding
for Continuing Grant entitled, "Industry/University Cooperative
Research Center for Material Handling"

Gentlemen:

A Request for Continued Support on the subject research project was recently submitted by my office; however, the letter from Dr. John White was inadvertently omitted. As we discussed, I am sending you the entire package again, for your review. I apologize for any delay or inconvenience this oversight has caused you.

Thank you for your assistance and support.

Sincerely,

Lynn Boyd
Contracting Officer

LB/gw

Addressee: In triplicate

Enclosures: Request for Continued Support:

- 1) Letter dated 1/8/85 from Dr. John White to Mr. Alex Schwarzkopf
- 2) Exhibit I: Budget
- 3) Exhibit II: Material Handling Research Center Membership

Blind Note: In our original submission of this request for continued support, the Request Letter from Dr. White was inadvertently omitted from the package. This letter, along with the complete package is sent to correct the oversight. Mr. Schwarzkopf has been apprised of the situation, and is expecting the complete package on January 29, Tuesday.



MATERIAL HANDLING RESEARCH CENTER
765 FERST DRIVE, NW
FRANK F. GROSECLOSE BUILDING
404-894-2362

January 8, 1985

Mr. Alex Schwarzkopf
National Science Foundation
1800 G Street, NW
Washington, DC 20550

Dear Mr. Schwarzkopf:

The purpose of my letter is to request continued support from the National Science Foundation for the development of the Material Handling Research Center into a strong industry/university cooperative research program. Such support will be for the third year of our previously proposed five year program of NSF funding. As previously proposed, NSF support in the amount of \$150,000 is planned for the third year of operation for the Material Handling Research Center. Consistent with previous years, NSF support is used to cover administrative costs for the Center.

As shown in the attached budget, it is proposed that the National Science Foundation provide 25 percent time support for the Director and Associate Director for the Center, 12.5 percent time support for the NSF Evaluator, and 100 percent time support for a secretary and an administrative assistant.

Currently, 28 companies are supporting the Material Handling Research Center. Of these, 20 are founding members; 8 companies have been added since membership was reopened effective October 1, 1984. The new members include Burlington, Burroughs, Coors, Eaton Kenway, Ford, Logan/Figgie, 3M, and TRW. Three of the founding members terminated their membership after 2 years: Boeing, Lyon Metal Products, and Sears. We anticipate that membership will increase to a total of 30 during the third year. A membership ceiling of 35 has been established in order to ensure that the research needs of each member are met.

The research agenda for the Center has evolved into a number of continuing programs, as well as specific projects authorized by the industry members. The continuing programs are: factory automation, warehouse automaton, robotics, advanced sensors, and logistics.

During the past year, the industry members voted to allow the Center to perform contract research for organizations other than the member companies. As a result, Georgia Tech's Vice President for Research has directed all units of the University that perform material handling research to perform such research under the auspices of the Material Handling Research Center.

Another significant event that occurred during the past year was the Second Annual Material Handling Research Forum. Attendance totaled 137, of which 54 were from non-member companies. This was the first time attendance was open to the public. Financially, the Forum netted \$10,000 for the Center.

A preliminary analysis indicates more than 15 graduate students supported by the Material Handling Research Center have graduated. Of these, at least 7 completed theses and/or dissertations. A total of 20 technical reports have been published and distributed to the member companies. Attendance at our Industry Monitors Meetings has averaged approximately 65 over the 2-year period. Additionally, all of the founding member companies were visited at least once by MHRC faculty and/or students during the 2-year period.

The annual membership fee for industrial members continues to be \$30,000. Georgia Tech continues to commit annual support for the Center totaling at least \$200,000. Georgia Tech also returns to the Material Handling Research Center at least 50 percent of the overhead generated by the Center. Additionally, Georgia Tech's President and Vice President for Research have been extremely supportive of the Center; they have indicated that personnel and equipment support will be provided to meet the needs of the MHRC.

The feedback received from the member companies indicates a high degree of satisfaction with the performance of the Material Handling Research Center. We are confident that the Center will continue to grow and receive international recognition for its contribution to its members and the field of material handling.

We appreciate very much the support received from the National Science Foundation and look forward to continued support during the third year. If you have any questions regarding the Material Handling Research Center, please do not hesitate to convey them to me.

Sincerely,

John A. White, Ph.D.
Director

JAW:fb

cc: Dr. T. E. Stelson
Dr. A. B. Sheppard
Dr. F. A. Rossini
Dr. M. E. Thomas
Mr. G. D. Hutchison
Mr. R. D. Atkins

B-04-618

GEORGIA TECH RESEARCH CORPORATION

GEORGIA INSTITUTE OF TECHNOLOGY
ATLANTA, GEORGIA 30332-0420

Telex: 542507 GTRCOCAATL
Fax: (404) 894-3120

Phone: (404) 894-4817

Refer to: LB/B-10-618
03.107.000.86.002

16 January 1986

Intergovernmental Science and Public Technology
National Science Foundation
1800 G Street, N.W.
Washington, D. C. 20550

Attention: Alex Schwarzkopf, Program Official

Subject: Grant No. CDR-8300965; Request for Fourth (4th) Year Funding for
Continued Grant entitled, "Industry/University Cooperative Research
Center for Material Handling"

Gentlemen:

In accordance with NSF Grant Policies, the GTRC is pleased to submit the
Request for Continued Support on the subject research project.

We believe that the enclosed material will provide you with all necessary
information. However, if additional information is required, please contact Dr.
John White at (404) 894-2362 concerning the technical program. Contractual
matters should be referred to the undersigned at (404) 894-4817.

We appreciate the opportunity of submitting this request and look forward to
the possibility of continuing our work with you on this project.

Sincerely,

Lynn Boyd
Contracting Officer

LB/tjm

Addressee: In triplicate

Enclosure: Request for Continued Support - In triplicate

GEORGIA INSTITUTE OF TECHNOLOGY
ATLANTA, GEORGIA 30332-0205



MATERIAL HANDLING RESEARCH CENTER
765 FERST DRIVE, NW
FRANK F. GROSECLOSE BUILDING
404-894-2362

December 17, 1985

Mr. Alex Schwarzkopf
Program Manager
National Science Foundation
1800 G Street, NW
Washington, DC 20550

Dear Mr. Schwarzkopf:

We are requesting continued support from the National Science Foundation for the Material Handling Research Center which is now entering its fourth year. The proposed support of \$100,000 is part of the previously proposed five year program of NSF funding. Consistent with previous years, NSF support is used to help cover administrative costs for the Center.

As shown in the attached budget, it is proposed that the National Science Foundation provide 8 percent time support for the Director, 50 percent time support for the Associate Director, and 10 percent time support for the NSF Evaluator. These funds will also be used to support approximately 1.5 graduate research assistants.

Currently, 25 companies are supporting the Material Handling Research Center; of these, 16 are founding members. Intech Systems is no longer a member due to bankruptcy; SI Handling Systems terminated its membership due to internal financial difficulties; and General Electric and Caterpillar have not renewed their membership. The Kroger Company is our newest member company. We anticipate that membership will remain constant throughout the year with the possibility of one additional company.

The research agenda includes considerable support for continuing program areas; however, their names have been changed to better reflect the focus of the programs. The continuing programs are Manufacturing Systems, Warehousing/Logistics Systems, Flexible Automation Systems, and Intelligent Systems.

We had a successful Material Handling Focus '85 in September; 150 people attended the first Material Handling Users Conference during the first 2 1/2 days and 90 people attended the third Material Handling Research Forum the last 2 1/2 days. We netted over \$16,000 from the Forum and had many excellent presentations and interactions.

Mr. Alex Schwarzkopf
December 17, 1985
Page 2

During our first three years of operation we supported several outstanding graduate students; during the coming year we will graduate a number of the Ph.D. students who have been supported since the Center began. Twenty-three masters degree students and three doctoral students associated with the Center have been graduated. A total of 38 technical reports have been published and distributed to the member companies.

The annual membership cost, currently at \$30,000, will increase to \$40,000 as of October 1, 1986 to offset rising costs. Georgia Tech continues to support the Center through cost share at a level exceeding \$200,000 annually, in addition to returning overhead generated by the Center. We recently received the first payment toward a total of \$160,000 from the AT&T Foundation which will be used to purchase equipment.

We are continuing to receive feedback from our member companies which indicates a high degree of satisfaction with THEIR Center. Areas in which we wish to improve are in communication with our Monitors and IAB and in enhancing the quality of technical reports.

We genuinely appreciate the support received from the National Science Foundation and look forward to continued support during the fourth year of our venture. If you have comments or questions please convey them to me.

Sincerely,

John A. White, Ph.D.
Regents' Professor
and Director

JAW:fb

Enclosures

B-04-618

GEORGIA INSTITUTE OF TECHNOLOGY
ATLANTA, GEORGIA 30332-0205



MATERIAL HANDLING RESEARCH CENTER
765 FERST DRIVE, NW
FRANK F. GROSECLOSE BUILDING
404-894-2362

April 3, 1986

TO: J. W. Dees, Director, OCA

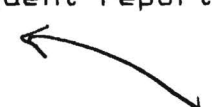
FROM: Dale Atkins, Associate Director, MHRC

SUBJECT: Delinquent Deliverables on B-10-618

In response to your memo regarding overdue deliverables, the Material Handling Research Center is submitting final reports on "official" NSF final report forms. The report that was submitted to NSF at the time was in the form of a proposal for the next years funding as this is a basically a five year grant. The proposal contained a report detailing the previous year's activities.

I do not believe that these need to be submitted to NSF as our commitment to them has been satisfied by the sections in our next year's funding proposal.

I would like to have the Center removed from having delinquent reports and would be happy to discuss this situation if need be.



COPY of "Final Project Report" To R. Hardaway 4/10
This Should Satisfy The 9/30/85 Requirement.



R Hardaway
B-10-618

FINAL PROJECT REPORT
NSF FORM 98A

PLEASE READ INSTRUCTIONS ON REVERSE BEFORE COMPLETING

PART I-PROJECT IDENTIFICATION INFORMATION

1. Institution and Address Georgia Institute of Technology Atlanta, Georgia	2. NSF Program ISTI	3. NSF Award Number ISI-8300965
	4. Award Period From 10/84 To 9/85	5. Cumulative Award Amount \$550,000.00
6. Project Title Industry/University Cooperative Research Center Material Handling Research Center		

PART II-SUMMARY OF COMPLETED PROJECT (FOR PUBLIC USE)

Currently, 25 companies are supporting the Material Handling Research Center; of these, 16 are founding members. ~~Intech Systems~~ is no longer a member due to bankruptcy; SI Handling Systems terminated its membership due to internal financial difficulties; and General Electric and Caterpillar have not renewed their membership. The Kroger Company is our newest member company. We anticipate that membership will remain constant throughout the year with the possibility of one additional company.

The research agenda includes considerable support for continuing program areas; however, their names have been changed to better reflect the focus of the programs. The continuing programs are Manufacturing Systems, Warehousing/Logistics Systems, Flexible Automation Systems, and Intelligent Systems.

We had a successful Material Handling Focus '85 in September; 150 people attended the first Material Handling users Conference during the first 2 1/2 days and 90 people attended the third Material Handling Research Forum the last 2 1/2 days.

PART III-TECHNICAL INFORMATION (FOR PROGRAM MANAGEMENT USES)

1. ITEM (Check appropriate blocks)	NONE	ATTACHED	PREVIOUSLY FURNISHED	TO BE FURNISHED SEPARATELY TO PROGRAM	
				Check (✓)	Approx. Date
a. Abstracts of Theses			X		
b. Publication Citations					
c. Data on Scientific Collaborators					
d. Information on Inventions					
e. Technical Description of Project and Results			X		
f. Other (specify)					
2. Principal Investigator/Project Director Name (Typed) Dr. John A. White	3. Principal Investigator/Project Director Signature			4. Date 5 April 86	

FINAL PROJECT REPORT
NSF FORM 98A

PLEASE READ INSTRUCTIONS ON REVERSE BEFORE COMPLETING

PART I-PROJECT IDENTIFICATION INFORMATION

1. Institution and Address Georgia Institute of Technology Atlanta, Georgia	2. NSF Program ISTI	3. NSF Award Number ISI-8300965
	4. Award Period From 10/83 To 9/84	5. Cumulative Award Amount \$400,000.00
6. Project Title Industrial/University Cooperative Research Center Material Handling Research Center		

PART II-SUMMARY OF COMPLETED PROJECT (FOR PUBLIC USE)

Currently, 28 companies are supporting the Material Handling Research Center. Of these, 20 are founding members; 8 companies have been added since membership was reopened effective October 1, 1984. The new members include Burlington, Burroughs, Coors, Eaton Kenway, Ford, Logan/Figgie, 3M and TRW. Three of the founding members terminated their membership after 2 years: -3 Boeing, Lyon Metal Products, and Sears. We anticipate that membership will increase to a total of 30 during the third year. A membership ceiling of 35 has been established in order to ensure that the research needs of each member are met.

The research agenda for the Center has evolved into a number of programs, as well as specific projects authorized by the industry members. The continuing programs are: factory automation, warehouse automation, robotics, advanced sensors, and logistics.

PART III-TECHNICAL INFORMATION (FOR PROGRAM MANAGEMENT USES)

1. ITEM (Check appropriate blocks)	NONE	ATTACHED	PREVIOUSLY FURNISHED	TO BE FURNISHED SEPARATELY TO PROGRAM	
				Check (✓)	Approx. Date
a. Abstracts of Theses			X		
b. Publication Citations					
c. Data on Scientific Collaborators					
d. Information on Inventions					
e. Technical Description of Project and Results			X		
f. Other (specify)					
2. Principal Investigator/Project Director Name (Typed) Dr. John A. White	3. Principal Investigator/Project Director Signature			4. Date 5 April 86	

cc: R. Hardaway
6/10/86

FINAL PROJECT REPORT
NSF FORM 98A

PLEASE READ INSTRUCTIONS ON REVERSE BEFORE COMPLETING

PART I-PROJECT IDENTIFICATION INFORMATION

1. Institution and Address Georgia Institute of Technology Atlanta, Georgia	2. NSF Program ISTI	3. NSF Award Number ISI-8300965
	4. Award Period From 10/82 To 9/83	5. Cumulative Award Amount \$200,000.00
6. Project Title Industry/University Cooperative Research Center Material Handling Research Center		

PART II-SUMMARY OF COMPLETED PROJECT (FOR PUBLIC USE)

The start-up of the Center was extremely successful, with 23 founding member companies actively participating in the MHRC. The proposed budget for the second year of operation is given in Exhibit I. A listing of the member companies is given as Exhibit II. Exhibit III provides a review of the establishment of the Center, as well as descriptions both of research performed during the first year and of research proposed for the second year.

To date, 12 technical reports have been published. We expect to publish approximately 20 technical reports during the second year of operation for the Center.

The Industry Advisory Board has authorized the addition of two additional member companies for the Center. Membership interest has been expressed by more than 30 firms. Hence, we do not anticipate any difficulties in filling the membership positions.

Among the major accomplishments during the first year was the receipt of over \$750,000 in equipment grants. Litton UHS donated \$600,00 of state-of-the-art material handling equipment, including two 7535 robots and PC computers; SI Handling Systems donated \$60,000 of mini-cartrac equipment to interface with automation equipment already available. Additionally, several other member companies have pledged to install their equipment for use by the MHRC. We anticipate equipment grants during the second year will total approximately \$100,000.

Approximately 18 research faculty, 25 graduate research assistants, and 5 support personnel were actively involved in the activities of the MHRC during the first year's operation. Turnover of research faculty and graduate research assistants has occurred. However, fortunately, there has been no turnover on the management team for the Center.

PART III-TECHNICAL INFORMATION (FOR PROGRAM MANAGEMENT USES)

1. ITEM (Check appropriate blocks)	NONE	ATTACHED	PREVIOUSLY FURNISHED	TO BE FURNISHED SEPARATELY TO PROGRAM	
				Check (✓)	Approx. Date
a. Abstracts of Theses			X		
b. Publication Citations					
c. Data on Scientific Collaborators					
d. Information on Inventions					
e. Technical Description of Project and Results			X		
f. Other (specify)					
2. Principal Investigator/Project Director Name (Typed) Dr. John A. White		3. Principal Investigator/Project Director Signature		4. Date 5 April 86	

GEORGIA TECH RESEARCH CORPORATION

GEORGIA INSTITUTE OF TECHNOLOGY
ATLANTA, GEORGIA 30332-0420

Telex: 542507 GTRCOCAATL
Fax: (404) 894-3120

Phone: (404) 894- 4817

Refer to: LB/03.107.000.87.002

25 July, 1986

Intergovernmental Science and Public Technology
National Science Foundation
1800 G Street, N.W.
Washington, DC 20550

Attention: Alex Schwarzkopf
Program Official

Subject: Grant No. CDR-8300965; Request for Fifth (5th)
Year Funding for Continuing Grant entitled,
"Industry/University Cooperative Research Center
for Material Handling"

Gentlemen:

In accordance with NSF Grant Policies, the Georgia Tech Research Corporation is pleased to submit the Request for Continued Support on the subject research project.

We believe that the enclosed material will provide you with all necessary information. However, if additional information is required, please contact Dr. John White at (404) 894-2362 concerning the technical program. Contractual matters should be referred to the undersigned at (404) 894-4817.

We appreciate the opportunity of submitting this request and look forward to the possibility of continuing our work with you on this project.

Sincerely. /

Lynn Boyd U
Contracting Officer

LB/sdm

Addressee: In triplicate w/enclosures
Enclosure: Request for Continued Support - In triplicate



MATERIAL HANDLING RESEARCH CENTER
765 FERST DRIVE, NW
FRANK F. GROSECLOSE BUILDING
404-894-2362

July 17, 1986

Mr. Alex Schwarzkopf
Program Manager
National Science Foundation
1800 G. Street, NW
Washington, DC 20550

Dear Mr. Schwarzkopf:

We are requesting continued support from the National Science Foundation for the Material Handling Research Center now entering its fifth year. The proposed support of \$50,000 is part of the previously proposed five year program of NSF funding. Consistent with previous years NSF support will be used to help defray administrative costs.

As shown in the attached budget, it is proposed that the National Science Foundation provide 12.5 percent time for the Director, 21.0 percent time for the Associate Director, and 4.0 percent time for the NSF evaluator.

We have based our budget for the upcoming year on having 20 member companies. We have received notification from Burlington Industries, Grumman, and TRW, that they will not be renewing their membership for the upcoming year, but we are currently discussing membership with two additional companies.

The research agenda, as a result of our last IAB/Monitors meeting, heavily reflects the interests and needs of our member companies. They had a large part in helping us select the items to be included.

During our first four years we have supported many outstanding graduate students. During this last year we graduated 5 Ph.D. students who have gone to augment or start Manufacturing/Material Handling research activities at five different universities. A total of 55 technical reports have been published and distributed.

The annual membership cost has been increased to \$40,000 per year as of October 1, 1986 to help offset rising costs. Georgia Tech continues to support the Center through cost

Mr. Alex Schwarzkopf
July 17, 1986
Page 2

share at a level exceeding \$200,000 annually. We recently received \$75,000 from the Georgia Tech Research Corporation to purchase additional lab equipment and we will be receiving an additional \$55,000 from AT&T for the purchase of equipment.

We are receiving feedback from our member companies that indicates that we are doing relevant, high quality research. We are continuing to address quality improvement in our technical reports and communication needs with our Monitors and IAB members.

We genuinely appreciate the support received from the National Science Foundation and use it to good advantage. We look forward to continued support during our fifth year. If you have questions or comments please convey them to me.

Sincerely,

BY DDA
John A. White, Ph.D.
Regents' Professor
and Director

JAW:mc

Enclosures

B-04-618

MHRC

MATERIAL HANDLING RESEARCH CENTER
765 FERST DRIVE, N. W.
ATLANTA, GEORGIA 30332-0205
(404) 894-2362

12/19/91

Alex Schwarzkopf
National Science Foundation
1800 G Street, NW
Washington, DC 20550

Dear Alex,

The recent reports from the Fraunhofer in Germany indicate that they have signed at least five companies to be members of FITT, and that the Federal Government has allocated additional funds for the development and exchange of technology.. They have two major research programs under way and several more being developed. We feel these developments conclusively demonstrate the successful formation of a center and lead us to conclude that we will be able to put together a technology exchange program that will provide as much value to us as to the Germans.

Therefore we are petitioning you to proceed with the Second Phase of the Study and anticipate that the \$30,000 for the Second Phase will be made available soon. Our pressure is to complete the project within the period of the original grant, which ends February 28, 1992 (including the No Cost Extension already granted). If the period of the grant can be extended it would be appreciated because it would offer us additional flexibility.

The Germans took an extraordinarily long time to sign members after the center was formed. While we believe that part of this is due to the constant state of turmoil that has existed in Europe during the last two years due to the collapse of the Berlin Wall followed by the collapse of Communism, we also believe that cultural differences account for part of the delay.

Attached is an Addendum to the Phase I report detailing the signing of the members for the German center and our plans to complete the study. Thank you for your support and patience with this project.

Sincerely,

Dr. Ira W. Pence, Jr. ✓

Dr. Gunter P. Sharp ✓

cc: R. Lauer

PHASE ONE REPORT
ADDENDUM

AN INTERNATIONAL COOPERATIVE
RESEARCH INITIATIVE INVOLVING
THE MATERIAL HANDLING RESEARCH CENTER
AT THE GEORGIA INSTITUTE OF TECHNOLOGY
AND (WEST) GERMAN
INDUSTRY/UNIVERSITY COUNTERPARTS

by
Dr. Gunter P. Sharp
Dr. Ira Pence

MATERIAL HANDLING RESEARCH CENTER
GEORGIA INSTITUTE OF TECHNOLOGY
ATLANTA, GEORGIA 30330-0205

December 19, 1991

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1.0 BACKGROUND

The Phase One Report of January 14, 1991, presented the results of a study by staff members of the Georgia Institute of Technology (GT), assisted by National Science Foundation (NSF) staff, of the establishment of an Industry/University Cooperative Research Center (I/UCRC) in the Federal Republic of Germany (FRG). The German center is named Forschungs Initiative Technologie (FIT) (Research Initiative for Technology), and is located at the University of Dortmund (UD) and the Fraunhofer Institute for Material Flow and Logistics (IML). The German center has an established legal structure, a permanent management, and financial support from government agencies. The major evolutionary process of the formation of the FIT center occurred during a 22-month period, from Feb. 1989 through Dec. 1990.

This Addendum presents information on recent activities in the German I/UCRC.

2.0 RECENT DEVELOPMENTS IN THE GERMAN CENTER

The major developments since the submittal of the Phase One Report relate to additional funding and the signing of five companies for the sponsorship of two research projects.

A commitment of DM 600,000 (\$340,000) has been obtained from the State of Northrhine-Westfalia (NRW). This is in addition to the DM 650,000 (\$370,000) obtained from the Bundesministerium fuer Forschung und Technology (BMFT). Thus, current public funding support is a total of DM 1,250,000 (\$710,000), spread over three years.

The two projects that are under way are (see Section 4.0):

1. Development of an autonomous vehicle for satellite storage systems.
2. Research on technical and economic feasibility of satellite storage systems for new distribution strategies.

The five companies that support the projects are (see Section 5.0):

- a. Scharpf Westfalia
- b. Netcon
- c. Gesellschaft fuer Prozessautomation (GPA)
- d. Gesellschaft fuer Datenmanagement und Unternehmensfuehrung (ManDat)
- e. Planungsgesellschaft fuer Transport- und Lagersysteme (VES)

Other developments relate to continued discussions between GT and FIT personnel concerning the possible forms of cooperation and suggestions for research projects. GT personnel made two trips to Europe where they met with FIT representatives.

In view of these developments, it is judged that the I/UCRC at the University of Dortmund is a success. **Therefore, as stated on page 10 of the Proposal dated July 11, 1989, which is the basis for the Grant, Phase Two of the research should begin automatically.**

3.0 PLAN FOR PHASE TWO OF STUDY

Phase Two involves a study of the development of a plan for the establishment of an International Industry/University/Government Cooperative Research Program (II/U/GCRP). Specifically, MHRC will study how MHRC and FIT can arrive at an organizational structure and research agenda for performing collaborative research.

3.1. General Guidelines

An initial concept for study of a possible II/U/GCRP has six parties involved in such a joint effort:

- U.S. government agency:
National Science Foundation (NSF)
- German government agencies and independent funding organizations:
Bundesministerium fuer Forschung und Technologie (BMFT)
State of Northrhine-Westfalia (NRW)
Fraunhofer headquarters organization
- U.S. research center:
Material Handling Research Center (MHRC) at
Georgia Institute of Technology (GT)
- German research center:
Forschungs Initiative Technologie within the
Gesellschaft fuer Materialflusssysteme at
University of Dortmund (UD) and
Fraunhofer Institute for Material Flow and Logistics (IML)
- MHRC member companies, represented by
Industry Advisory Board (IAB)
- FIT member companies, represented by
FIT Industry Advisory Board (FIT-IAB)

Section 3.13 and Appendix 17 of the Phase One Report give details of the relationships among these six parties under this initial concept.

The projects to be selected for collaboration should be of a type that will benefit the member companies of both MHRC and FIT. Ideally, the primary motivation for the projects performed by MHRC should come from FIT member companies, and the motivation for projects performed by FIT should come from MHRC member companies.

The projects within the shared research program should be of roughly equal value, as perceived by the member companies on both sides. In the case of projects that include a product development phase, the identification of the generic, pre-competitive research component, will facilitate the sharing of results of equal value. The unprotected rights of the projects will be shared among the members of MHRC and FIT.

It is expected that, in the first year of the collaborative research, the work performed by MHRC and FIT would represent separate research topics. The results will be shared, of course. It is expected that at some point in time some of the research will be a joint activity, requiring close coordination between MHRC and FIT.

The NSF and German ministries and agencies are expected to provide supplementary funds for a time period not to exceed five years, with the industry boards gradually taking the lead in funding.

3.2. Study of Approval Processes

During the operation of the II/U/GCRP, there will need to be a coordinated and simultaneous process for obtaining from the member companies the approval for the collaborative research program. The proposed research will include a study of the steps required and a possible timetable for establishing such an II/U/GCRP.

Concurrently, a study will be made of the steps needed by MHRC to seek approval from the Georgia Tech Research Corporation (GTRC), the contractual agency for Georgia Institute of Technology, and from the Board of Regents of the University System of Georgia.

Similarly, a study will be made of the steps needed by GMS/FIT to seek approval from any legal entities or government agencies, such as the University of Dortmund and the State of Northrhine-Westfalia.

3.3. Study of Negotiations with Government Agency in FRG

The UD/IML has already obtained funding from two government ministries in the FRG and has applied support from the FhG headquarters organization:

BMFT:	DM	650,000 over 3 years
NRW:	DM	600,000 over 3 years
FhG:	DM	600,000 over 3 years

These negotiations will continue throughout Phase Two until the additional funding has been secured or until it becomes evident that it will not be provided. The proposed research will study the progress of these negotiations.

3.4. Study of Negotiations between U.S. and FRG Government Agencies

The envisioned II/U/GCRP between MHRC and FIT may require a contract containing clauses on the sharing of patents, licenses, and copyrights for internal use by the two research centers and by the member companies. An inquiry will be made to determine if any of the shared rights must be approved by an agency of the U.S. Government, such as the Department of Commerce. Similarly, a study will be made of any approvals that FIT may need to obtain from any state or Federal agency concerning the sharing of patents, licenses, and copyrights.

3.5. Study of Administrative Mechanisms

3.5.1. Mechanisms. During Phase Two there will be a study to determine the mechanisms needed for project selection, project direction, results dissemination, ownership of the intellectual properties, management of the technology transfer, and procedure for the exchange of personnel.

The selection of the projects for research which will be shared will require the participation of all the parties involved, the industrial members in the FRG, the industrial members in the U.S., the MHRC, and FIT. Possibly, the agencies of the respective governments will also play an advisory role, since they may want to monitor that the requirement for quid pro quo is consistently adhered to.

It is anticipated that an arrangement can be achieved in which any member company in either center or any researcher associated with either research organization can propose that a certain area of work, a project, be considered for inclusion in the technology exchange program. A small committee selected from the research center would then review these programs for appropriateness; i.e., review them to be sure that no item of national importance and no item of particular commercial advantage to any member company is included, and to review them for possible interest to their counterpart in the other country. This process would occur in both centers.

The candidate projects that pass this initial screening would then be presented to the other centers, who would rank the desired projects in terms of their own interests. A committee composed of representatives of the interested parties would then use these rankings to help identify a set of shared research projects, on a quid pro quo basis. These recommendations would then be passed to the MHRC IAB and the FIT-IAB for final approval of the shared research agenda. The U.S. and FRG funding agencies would be invited to observe but would not participate in the decision process.

The details of the procedure and timing for the submission of candidate programs to this procedure, the level of detail in initial and subsequent proposals, the basis for budgeting/costing, the definition of deliverables, the process for the screening, and

the process for negotiating the actual programs to be implemented and exchanged will all have to be studied in Phase Two of this effort.

The results of the II/U/GCRP research have to be disseminated to the member companies in such a manner to facilitate the timely transfer of technology. Further, results that are of no particular commercial advantage should be made available to researchers in the world community to avoid duplication of effort. Policies for the level of detail reported, the availability of researchers for participation in a company's attempt to use the results, the period of initial proprietary restriction, any extension of the proprietary period, and the review process for any material submitted for publication or release will all be studied in Phase Two of this effort. The basic guidelines used within the I/UCRCs in the U.S. will serve as a model, but particular needs and customs of the FRG will have to be accommodated.

The ownership of the intellectual properties, patents, copyrights, etc., and the rights to negotiate licenses and sale of these properties, as well as the distribution of the income from such sales or licenses will need to be studied. There appears to be a common basis for a quid pro quo arrangement, as the existing procedures in the two countries are similar.

The daily management of the technology exchange will be the responsibility of individuals within the two research organizations. The prerogatives, responsibilities, and authority of these individuals must be studied to determine how the programs can proceed smoothly without placing an undue burden upon any of the parties involved.

Since it is sincerely believed that technology transfer is best achieved via the exchange of persons, the details of compensation and living expenses, period of exchange, frequency of exchange, office and support provided, etc., will need to be studied during Phase Two. The exchanges that have already occurred provide a starting basis for this part of the research.

3.5.2. Effect of U.S. Observers in Study. It is anticipated that the U.S. observers will need to be more active in the further development of FIT. There is a potential role for GT/MHRC staff and possibly NSF staff in at least two aspects of FIT, the structure of the organization and the marketing to companies.

It is noteworthy that the major change in structure of the German I/UCRC occurred during a time when there were no U.S. observers in the FRG, during the period Nov. 1989-Feb. 1990. Also, Mr. Schmidt (IML), who is the one German person most familiar with the U.S. I/UCRC concept, was absent from the FRG most of that time. The ability of the U.S. observers to share their experiences with cooperative research during Phase Two of the study will be a factor in the evolution of the FIT structure so that it resembles more closely that of MHRC. One possible way to do this is to increase the share of money that flows to GMS and allocate that, with the approval of the FIT-IAB, to projects where the detailed results are shared with all FIT members, and not just consortia members.

The current trend is for the FIT members to contribute larger sums than a typical member of U.S. I/UCRC does. This may be a reason for the slow response to the marketing efforts. It is anticipated that another meeting needs to be held with representation from companies that are FIT members and potential members. At this meeting the issues of project size, types of projects, types of members, etc., would be revisited. A stronger presentation of the GT/MHRC capabilities, and the potential benefits for the German companies, is also needed. Again, the U.S. observers could be a valuable resource in such efforts.

3.6. Study of the Development of Multi-Year Funding Plan, with Government Agency Phaseout After 5 Years

Phase Two will result in a report of what type of agency funding plan would be needed for the technology exchange. However, an indefinite funding by the government agencies is not intended. Rather, it is anticipated that the government funding will be limited to about five years.

During Phase Two the details of the funding phaseout, and the establishment of progressive goals for the magnitude of non-government-sponsored exchange programs, possibly as a requirement for continued government participation, will be studied. This effort will include discussions with funding agencies and the FIT participants.

It is believed that the dual mechanisms, a) the exchange after-the-fact of results achieved; and b) a budget set aside for conducting work expressly for exchange, should provide a stable means of continuing the technology exchange after government funding expires.

3.7. Study of Center Evaluation Procedures

The cultural setting of FIT is different from that of the typical U.S. I/UCRC. The diagnostic tools to judge the operation of the German I/UCRC will need to be selected and/or developed. It is expected that the U.S. observers can assist the evaluator of FIT, Professor Jehle (UD Sociology Department), in this effort.

The establishment and operation of an II/U/GCRP will require a formal evaluation mechanism to provide feedback to the center directors on the subjects of organizational and management aspects, relations with member companies, collaborative research activities, and the exchange of research results. Phase Two will include a study of what type of evaluation mechanism would be needed.

It is likely that such a mechanism will require an interface between an MHRC evaluator and the counterpart evaluator for FIT. New procedures would be included to evaluate the various aspects of the international cooperation.

3.8. Final Report, Phase Two

A final report on the results of the study and discussions in Phase Two will be prepared and delivered.

4.0 DESCRIPTIONS OF CURRENT PROJECTS IN GERMAN CENTER

4.1. Development of an Autonomous Vehicle for Satellite Storage Systems

The objective of this project is to develop an autonomous vehicle that can store and retrieve unit loads in a high-density storage/retrieval system, as well as travel outside the system. Existing satellite storage/retrieval systems suffer from a number of weaknesses, such as bottlenecks at the interface points with other systems. The desired vehicle would have some of the characteristics of an automated guided vehicle (AGV), but would be simpler and smaller, and therefore more economical and easier to control. Project work actually began in November 1990, although contracts between the sponsoring companies and FIT were not signed until this year. The project budget is DM 199,000 (\$113,000).

4.2. Research on Technical and Economic Feasibility of Satellite Storage Systems for New Distribution Strategies

The objective of this project is to develop a procedure for evaluating and selecting storage/retrieval systems based on satellite vehicle and shuttle transfer vehicle designs. Special consideration will be given to the utility of such high-density systems in businesses that are operating with new distribution strategies. A pilot application is also envisioned. Project work actually began in May 1990, although contracts between the sponsoring companies and FIT were not signed until this year. The project budget is DM 606,000 (\$344,000). A major portion of the budget is for the pilot application.

5.0 DESCRIPTIONS OF COMPANIES IN GERMAN CENTER

5.1. Gesellschaft fuer Prozessautomation (GPA)

The company, located in Dortmund, was founded in 1984 as a limited liability corporation engaged in selling engineering and research services, especially for process automation and material flow systems. The 25 employees generated a volume of DM 4.5 million (\$2.5 million) in 1990.

5.2. Gesellschaft fuer Datenmanagement und Unternehmensfuehrung (ManDat)

The company, located in Dortmund, was founded in 1989 as a limited liability company offering consulting services in the logistics field. The 10 employees generated a volume of DM 1.2 million (\$700,000) in 1990.

5.3. Planungsgesellschaft fuer Transport- und Lagersysteme (VES)

The company, located in Dortmund, was founded in 1975 as a limited liability corporation offering consulting services in the area of factory modernization, logistics, and warehousing. The 18 employees generated a volume of DM 1.5 million (\$859,000) in 1990.



B-04-618

MATERIAL HANDLING RESEARCH CENTER
765 FERST DRIVE, N. W.
ATLANTA, GEORGIA 30332-0205
(404) 894-2362

December 15, 1988

Mr. Alex Schwarzkopf
Program manager
national Science Foundation
1800 G Street, NW
Washington, D.C. 20550

Dear Mr. Schwarckopf:

In the fifth and final year (1987-88), under the support of NSF, the Material Handling Research Center had a very productive year. There was increased participation in the monitors' meetings held in May and November; the TOTE software package was completed; a standard interface for the Center software was developed; a preliminary version of STOR was distributed; the "Linehaul-Backhaul" research by Dr. Charlotte Jacobs-Blecha was completed; a new cover for Center publications was introduced; user summary sheets for all Center reports were developed; 7 reports were completed and distributed; a new video tape was released on selected warehousing and logistics research projects for distribution within the member companies; a staff retreat was held and the IAB met in called meetings to discuss the future strategy and goals for the Center; workshops on AGVS Design and Orderpicking were held in late summer with full attendance for each; the Center began serving as Secretariat for the AS/RS Users Association and provided speakers and lab tours for one day of their week long conference in May; 57 trips were taken by staff and/or student personnel in support of member companies and new member company recruitment; the Focus Conference in September had approximately 100 in attendance and the Material Handling Short Course co-sponsored by the MHRC, had full attendance for the week's program in April. During the year there were 19 professional staff, 1 visiting scholar, 38 graduate research assistants, and 2 undergraduate assistants participating in the program. The Center has received several new research grants and contracts and numerous awards and recognitions made to staff personnel.

A pilot program of joint research with WHRC (Web Handling Research Center) at Oklahoma State University was initiated and work is underway. Interaction between the two centers involved attendance from the respective Centers representatives at the others monitors and IAB meetings, in addition to the shared research. Future joint meetings will be held as necessary.

A joint research project with the University of Puerto Rico was initiated this year and negotiations are in progress to solidify plans for joint research with the Fraunhofer Institute in West Germany. Explorations of additional joint research are ongoing with other universities and research centers.

Mr. Alex Schwarzkopf
December 15, 1988
Page 2

There were 25 member companies for this fifth year. Overall, the MHRC continues to move forward in developing new programs of joint center research while maintaining ongoing programs as recommended by the IAB. Because of the past and continued support of the NSF, member companies and Georgia Tech, the MHRC has established itself as THE Center for material handling research in the United States. With the support and guidance rendered by the NSF, and the continued interest in material handling by the member companies, the Center accepts with enthusiasm the challenge of preparing America for her future in material handling technology.

We genuinely appreciate the support received from the National Science Foundation during this five year period. We realize that the success of the Material Handling Research Center would not have been possible without NSF's support and guidance.

If you have questions or comments I will be happy for you to contact me.

Sincerely,

Dr. Ira W. Pence, Jr.
Director

IWP:fb

MHRC

MATERIAL HANDLING RESEARCH CENTER
765 FERST DRIVE, N. W.
ATLANTA, GEORGIA 30332-0205
(404) 894-2362

July 19, 1989

Mr. Alex Schwarzkopf
Program Manager
NATIONAL SCIENCE FOUNDATION
1800 G Street, NW
Washington, DC 20550

Dear Mr. Schwarzkopf:

The remarks that follow are submitted as the Annual Report for the Material Handling Research Center.

It has been a very busy and challenging year for the faculty, staff and students of the MHRC. The member companies of the MHRC have made possible the growth and expansion of the Center as the Industry Advisory Board so ably guided us in the research agenda and the various programs of expansion. The basic thrust for the Center has been and will always be to meet the material handling needs of the member companies. It was toward this end that the following accomplishments were realized and future plans proposed for continued growth and development:

- Membership - 23 member companies including commitments from J&J and SysteCon/Coopers & Lybrand
- 7 additional faculty participating in our research; Ed Frazelle, Research Engineer with MHRC accepted a faculty position in Georgia Tech's ISyE Department and will continue to contribute to the Center
- Total budget of \$1.77 million with approximately \$1.5 million expended on research agenda with 16 projects approved by Board for 1988-89
- Two workshops offered as service to member companies: Order Picking Workshop (presented three times) and AGVS Design Workshop (to be offered again in fall '89); in-house Advanced Warehousing two-day workshop presented for GE in May
- First Roundtable Discussion hosted by GM in April on "Off-Wire Guided Vehicles" with six participating member companies
- Co-sponsorship with School of ISyE of the prestigious 39TH Annual MATERIAL HANDLING SHORT COURSE which again drew record attendance
- Sponsorship of MATERIAL HANDLING FOCUS '89 to be co-sponsored with the International Material Management Society, September 11-13, 1989

- Job Fair offered at November Monitors Meeting provided member companies "first look" at Tech graduates specializing in material handling
- In conjunction with IFS Publications, an English publication house, the first book by the Center has just been completed "in-house" and will be released this summer; the first volume in a series on Current Topics in Material Handling and Logistics and edited by Drs. John A. White and Ira W. Pence
- NSF grant awarded to an outstanding minority undergraduate student for second year
- First MHRC newsletter published with plans for quarterly editions; video taping of selected research presentations continued to increase communication within member companies regarding research projects
- Program initiated and funded by NSF for cooperative research between MHRC and University of Puerto Rico on queueing networks
- Ten reports (technical and/or thesis/dissertations) published and distributed to member companies on continuing six-month proprietary basis
- Negotiating a program of joint research and technology exchange with Fraunhofer Institute in West Germany to be funded by NSF for five-years at \$125,000 annually
- Joint program with Oklahoma State University's WEB Handling Center on paper handling research continued into second year
- Center continues to act as Secretariat for AS/RS Users' Association which has added to ever expanding database of approximately 1,400 entries
- Travel was made by faculty to 29 conferences/meetings and 34 visits were made to member companies
- Responding to request by NSF to provide leadership for a pilot program for a consortium of three universities pursuing research in material handling - opportunity for additional funding and coordination of research efforts with additional benefits to member companies; initial planning scheduled this summer
- MHRC to co-sponsor, with NSF and the Material Handling Industry of America, a Material Handling Research Colloquium next summer for 40 academic faculty
- Just completed Canadian sponsored mission to review manufacturing and material handling research in Canada for purpose of possible joint research

The move toward international cooperation is evident in the overall program. Other leaders in material handling agree with us that this is the most advantageous approach to research as we compete for the edge in material handling technology in the '90's. We will endeavor to explore every opportunity and possibility which will enhance advancement and productivity for the Center's member companies. We are anticipating the "start up" of the Manufacturing Research Center (MaRC) at Georgia Tech next year and the opportunities this new Center will afford us.

Page 3

We are proud of the Center's past record, excited about its present program and challenged by the future as we plan and work together with the member companies to improve material handling technology in the U.S.

Sincerely,

Dr. Ira W. Pence
Director

IWP:fb

PLEASE READ INSTRUCTIONS ON REVERSE BEFORE COMPLETING

PART I-PROJECT IDENTIFICATION INFORMATION

1. Institution and Address Georgia Tech Research Corporation Georgia Institute of Technology Atlanta, Georgia 30332-0420	2. NSF Program Engineering	3. NSF Award Number ECD-8300965
4. Award Period From 1/1/83 To 8/31/91	5. Cumulative Award Amount \$ 1,187,000	
6. Project Title "Industry/University Cooperative Research Center For Material Handling."		

PART II-SUMMARY OF COMPLETED PROJECT (FOR PUBLIC USE)

Under the encouragement of this grant from the NSF an Industry/University Cooperative Research Center was formed to perform research in the area of material movement, storage, and control.

Approximately 40% of the cost of manufacturing in the United States is due to material handling, i.e., the acquisition of material, moving and storing it between value-adding operations, and storage and distribution of finished goods. While a major cost of doing business, it is not widely recognized in the US because material handling is usually distributed across several of the traditional functions. The Japanese have recognized the logistics of manufacturing as a major cost element and thus have introduced concepts like Just-in-Time.

The Material Handling Research Center formed a consortium of industrial firms to explore the science underlying material handling and develop analytical tools to assist the Industrial Engineer and his management in developing more efficient procedures, and to transfer these tools into industrial practice.

The Center has been successful in meeting all its goals. It is now a growing, self-sufficient research organization with research activity on six campuses, with support from such diverse industries as fresh fruit (Chiquita, Dole), consumer goods (Levi Strauss), automotive (Ford, GM), electronics, (AT&T, Compaq, DEC, IBM), and a host of others. It has developed techniques which have resulted in major savings for its member companies. The largest documented savings were by a major electronics firm with reduced WIP by \$100 million and reduced personnel required by \$3 million/year.

PART III-TECHNICAL INFORMATION (FOR PROGRAM MANAGEMENT USES)

1. ITEM (Check appropriate blocks)	NONE	ATTACHED	PREVIOUSLY FURNISHED	TO BE FURNISHED SEPARATELY TO PROGRAM	
				Check (✓)	Approx. Date
a. Abstracts of Theses			✓		
b. Publication Citations			✓		
c. Data on Scientific Collaborators			✓		
d. Information on Inventions			N/A		
e. Technical Description of Project and Results			✓		
f. Other (specify)					
2. Principal Investigator/Project Director Name (Typed) Ira Pence			4. Date 7/1/91		

PART IV - SUMMARY DATA ON PROJECT PERSONNEL

NSF Division _____

The data requested below will be used to develop a statistical profile on the personnel supported through NSF grants. The information on this part is solicited under the authority of the National Science Foundation Act of 1950, as amended. All information provided will be treated as confidential and will be safeguarded in accordance with the provisions of the Privacy Act of 1974. NSF requires that a single copy of this part be submitted with each Final Project Report (NSF Form 98A); however, submission of the requested information is not mandatory and is not a precondition of future awards. If you do not wish to submit this information, please check this box ☐

Please enter the numbers of individuals supported under this NSF grant.
Do not enter information for individuals working less than 40 hours in any calendar year.

*U.S. Citizens/ Permanent Visa	PI's/PD's		Post- doctorals		Graduate Students		Under- graduates		Precollege Teachers		Others	
	Male	Fem.	Male	Fem.	Male	Fem.	Male	Fem.	Male	Fem.	Male	Fem.
American Indian or Alaskan Native												
Asian or Pacific Islander			1		10			1				
Black, Not of Hispanic Origin					5		1	2				
Hispanic			1		15	10						
White, Not of Hispanic Origin	2		12	4	100	60	2	3				
Total U.S. Citizens	2		14	4	130	70	5	6				
Non U.S. Citizens			4		50	10						
Total U.S. & Non-U.S. ...	2		18	4	180	80	5	6				
Number of individuals who have a handicap that limits a major life activity.												

*Use the category that best describes person's ethnic/racial status. (If more than one category applies, use the one category that most closely reflects the person's recognition in the community.)

AMERICAN INDIAN OR ALASKAN NATIVE: A person having origins in any of the original peoples of North America, and who maintains cultural identification through tribal affiliation or community recognition.

ASIAN OR PACIFIC ISLANDER: A person having origins in any of the original peoples of the Far East, Southeast Asia, the Indian subcontinent, or the Pacific Islands. This area includes, for example, China, India, Japan, Korea, the Philippine Islands and Samoa.

BLACK, NOT OF HISPANIC ORIGIN: A person having origins in any of the black racial groups of Africa.

HISPANIC: A person of Mexican, Puerto Rican, Cuban, Central or South American or other Spanish culture or origin, regardless of race.

WHITE, NOT OF HISPANIC ORIGIN: A person having origins in any of the original peoples of Europe, North Africa or the Middle East.

THIS PART WILL BE PHYSICALLY SEPARATED FROM THE FINAL PROJECT REPORT AND USED AS A COMPUTER SOURCE DOCUMENT. DO NOT DUPLICATE IT ON THE REVERSE OF ANY OTHER PART OF THE FINAL REPORT.

Final Report
NSF Grant ECD - 8300965

Material Handling Research Center

The Material Handling Research Center, and I/UCRC, was formed in 1982 and has had support under this grant from 1983 through 1991. During this period the Center reached a status of self-sufficiency. It is continuing as a healthy center with the stable support of about twenty member companies.

During this period the Center developed from a fledgling operation with programs largely selected by faculty to a true cooperative research center with an agenda which is stimulated by industrial concerns and which develops solutions starting from basic principles.

The Center conforms in all ways to the current model of an I/UCRC and has introduced several new approaches, such as the one-page proposal format, which have been adopted by many other centers. Because of its success and innovative approaches, it continues to be used as a model by NSF for new centers. About a dozen have sought advice from and/or visited the Center to obtain a first hand observation of its operation.

The technical progress of the Center has been documented in the annual and technical reports. The Center dominates the field of Material Handling Research in the U.S. It is recognized as a major force by the industry association, MHI. MHI and the Center collaborate in special research colloquiums, and the Center provides members to serve on MHI's education committee (CICMHE). The Center interacts with the other major societies, IIE, CLOM, IMMS, ASRSUA, etc., and may be able to play a major coordinating role in the future.

The Center has explored the possibilities of technology transfer with other countries and is negotiating a technology sharing contract with the Fraunhofer Institute in Germany. Discussions have been held with the Canadian government and universities, and a review of Japanese technology has been conducted by one of our researchers.

The Center has out grown the ability of a single campus to provide the high-quality academic researchers needed to perform the research desired by our member companies. It has recently expanded to include three other universities in the southeast and expects to expand to a national presence.

The Center has been blessed with a continuity of researchers with only one change in Director and a few additions to the research program area leaders. All the original research area leaders are still part of the Center and coordinating the research done on the multiple campuses. While a few of the individual research project leaders have spun off to form other centers or companies addressing specialized niches, most remain as irregular contributors to the Center.

In some cases the original project work within the Center has led to major independent grants from NSF or other sponsors to pursue an important line of research. In other cases work that was started as basic research with no application has led to discoveries that support the needs of the members in which case the investigators have received follow-on support from the Center. In other cases it has been possible to jointly fund a research project either with NSF, another center on the Georgia Tech campus, or one or more industrial firms. This collaboration has provide an important element in extending the Center's ability to serve its members.

The Center has entered into special projects with other I/UCRCs under the sponsorship of the NSF TIE program. Common features of successful projects are that the research is of core interest to both centers and has an immediate connection to on-going research. Under these circumstances the research collaboration continues after the NSF initiation grant ends.

Deliberate attempts to explore the boundary between two centers (to determine if there are vital gaps not being pursued by either center) were not successful. The lack of success does not seem to be related to the technical content or importance of the research, but to the fact that it was not central to either center and thus was a 'distraction' for both. Under these circumstances it did not enjoy significant peer interest; was not in the mainstream of activity; did not have sufficient prestige to interest the best graduate students; and thus, once NSF support ceased, the collaboration ended.

The Center has participated in RUI/PUI projects which were helpful in establishing the credibility of new, young minority researchers on campuses not noted for their research activity. These programs were useful in extending the efforts of the Center. In particular, when the faculty involved were graduates of the Center the line of research used for the doctoral thesis was continued and expanded and the additional results reported to the member companies.

The major need in the Center, as this grant draws to a close, is for additional discretionary funds that could be used to convert some of the results into improved curricular material which could be integrated in the academic course work at many universities, thus updating the material taught to students. It seems a shame that the course material used on most campuses

in our field is more than ten years old and has been rendered obsolete by the research conducted at the Center, but that the lack of funds to shape this material into easily taught modules prevents its utilization. It is unreasonable to expect the companies supporting the research to place any emphasis on this activity when they are consumed by the need to respond to the pressures of international competition.

ERCs have the dissemination of results into courses of study as one of their funded objectives. It would seem that the I/U CRCs offer a larger body of knowledge of a more diverse nature. Much of this knowledge will remain unavailable to instruction if an active program is not instituted to capture and mold it into texts or modules that can be substituted by instructors into existing courses.

During the period covered by this grant 103 technical reports were written and approximately 330 journal articles and conference presentations gave credit for support from the NSF. Twenty-one (21) Ph.d degrees and 62 MS degrees were awarded to students supported by the Center during their graduate studies. 35 faculty have received support during this time. This grant leveraged approximately \$7 million of industrial support and approximately \$2 million of state support. into areas of research of national importance.